LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO
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Progress Report

The activity under this grant consists of a basic theoretical and experimental research program in planetary atmospheres that also serves as a basis of support for an integrated space experiment program. The space experiments include the Mariner '67 ultraviolet photometer, the Mariner '69 ultraviolet spectrometer, the OGO-C and D ultraviolet spectrometers, the OGO-E and F ultraviolet photometer, and sounding rocket ultraviolet spectrometers and photometers. With the exception of the sounding rocket program, these experiments have been funded by the appropriate project.

Mariner '67 Ultraviolet Photometer

The successful launch of Mariner V has resulted in unique measurements of the earth's atomic hydrogen corona by the ultraviolet photometer experiment. During the first sixteen hours of the mission, the rolling mode of the spacecraft permitted some thirty observations of Lyman-alpha radiation on the sunward side of the earth at distances 8,000 to 120,000 km. It is anticipated that it will be possible to analyze this data in terms of the density, temperature, and source of hydrogen atoms in the earth's exosphere.

Lyman-alpha radiation from the galaxy was also measured during the initial phase of the mission. On day one and again on day five, an extended source in the constellation Vela was observed and identified with the Milky Way. It is anticipated that the analysis of this data will provide information on the properties of interstellar matter in the direction of the observation.

Theoretical Program

Radiative Transfer - C. Hord

Radiative transfer calculations associated with the transport of resonance radiation in planetary atmospheres are continuing. Specific problems being considered include; resonance scattering in planetary exospheres, the effect of the assumption of either coherent scattering or complete redistribution of frequency on radiative transfer solutions, and the problem of finding an "H transfer function" which gives a better description of the transport of Lyman-alpha radiation below 120 km in the Earth's atmosphere.

Excitation of the dayglow and auroral spectra - M. Rees

With the expectation that individual lines and bands in the UV region of the spectrum will be measured as a function of altitude, computations are being carried out predicting expected photon fluxes. In the auroral case we begin with the primary electron energy spectrum, determine the secondary spectrum by various approximate methods at our disposal, and calculate the excitation rate of the individual spectral features as a function of altitude. One of the important steps in the calculations involves the energy degradation of secondary electrons. Heretofore the continuous slowing down approximation has been used, and discrete energy jumps have been neglected. This introduces a considerable error. Dr. Ian Stewart, who will join LASP in September, 1967, has solved the discontinuous energy degradation problem for the dayglow and will apply the technique to the auroral problem. Among the large number of cross sections relevant to auroral excitation in the UV, only a small fraction have been measured in the laboratory. Work is continuing on evaluating the possibilities of extending the laboratory work to include several other bands prominent in the auroral spectrum.

Ultraviolet Spectra of Comets - C. Barth

In conjunction with the five month visit of L. Biermann to JILA, an analysis was made of the ultraviolet emissions to be expected from comets. It was determined that atomic hydrogen 1216 A° and atomic oxygen 1304 A° radiations could be measured with an UV photometer of the type now being used on Mariner V. It is anticipated that a joint proposal will be made with the Max Planck Institute for Physics and Astrophysics and the Laboratory for Atmospheric and Space Physics to conduct rocket experiments to measure comets in the UV.

Laboratory Experimental Program

Molecular Spectroscopy - V. Degen

Spectroscopic equipment is being set up to measure upper atmosphere molecular band systems in the laboratory under both high and moderate resolution. A vacuum Ebert 1.8 meter spectrometer will be used for the high resolution studies. A spectrogram obtained previously in the laboratory of the oxygen Herzberg bands has been analyzed with electronic averaging equipment. The technique has been written up and is to be published in Applied Optics.

Personnel

Dr. Gary Thomas has accepted a joint appointment in the Laboratory for Atmospheric and Space Physics and the Department of Astro-Geophysics as an Assistant Professor. It is anticipated that he will provide guidance to the theoretical program, particularly in the area of radiative transfer and heat conduction in planetary atmospheres and in the analysis of OGO E and F data in Lyman-alpha scattering by atomic hydrogen.

Dr. Ian Stewart has accepted a two year appointment in the LASP as a Research Associate. It is anticipated that he will continue to work on calculations of the excitation of the dayglow and aurora by electron bonbardment.

Drs. Charles Hord, Vladimir Degen, and Manfred Rees continue as Research Associates in the LASP.

The following graduate students are associated with and/or supported by this grant.

J. B. Pearce
W. Sharp
J. Ajello
G. Meira
G. Patterson
D. Anderson
D. Rusch

In related activities, C. A. Barth gave a course during the spring 1967 semester entitled, "The Ionosphere and Magnetosphere." There were 18 students registered.

Also in related activities, R. B. Norton completed his Ph.D. dissertation entitled "The Ionized Constituents in the 100 to 300 Kilometer Region of the Earth's Upper Atmosphere." The thesis preparation was supervised by C. A. Barth. Dr. Norton's activities were supported by the Environmental Sciences Service Administration. The abstract of the thesis is attached.

ABSTRACT

Norton, Richard Bryce (Ph.D., Astro-Geophysics)

The Ionized Constituents in the 100 to 300 Kilometer Region of the Earth's Upper Atmosphere

Thesis directed by Dr. Charles A. Barth

A model of the upper atmosphere ion composition is constructed by combining the best available data for neutral composition, solar UV and X-ray flux, ionization cross sections and efficiencies, and molecular reaction rates. This model is compared with the ion and electron density profiles that have been obtained by a variety of means, including rocket and satellite experiments as well as ground based radar experiments. Because of their large coefficients in reactions with the ions, the atomic nitrogen (N) and nitric oxide (NO) concentrations are estimated. The calculated NO concentrations agree reasonably well with observations above 125 km but depart drastically at lower altitudes. Allowing for reactants that are nonthermal or in excited states (e.g., $N(^2D) + O_2$) may resolve this discrepancy. Atomic nitrogen concentrations of the order of $10^7 cm^{-3}$ or greater are estimated for the E and F1 region.

The model is found to agree quite well with the observed height profiles of ion composition and is used to compute the ion concentration at various heights as a function of time (diurnal, seasonal and solar cycle) and compared with observation. However, in order to use the laboratory coefficient for the O^+ reaction, atomic oxygen concentrations must be used that are larger than the rocket-borne mass spectrometer observations but that are consistent with the ultraviolet absorption measurements.

Good agreement is obtained with daytime electron density variations although diurnal variations in neutral composition are important in explaining the upper F region. The nighttime E region requires a source which we postulate to be scattered Ly β. The nighttime F1 region appears to decay to quite low densities, of the order of $10^2 cm^{-3}$ except during magnetically disturbed periods when a layer is formed. It is argued that this layer is not likely to be due to transport alone. A small flux of energetic electrons is suggested as the ionizing source. Seasonal variations in F region electron densities are interpreted in terms of neutral composition changes. It is hypothesized that a seasonal change in the height of turbopause, which mainly alters the atomic oxygen concentration, is responsible for these changes. Solar cycle changes in the maximum density of the various ionospheric layers are related to changes in the solar ionizing flux. However, temperature induced changes in the neutral atmosphere are also important at fixed heights in the F region.

The model is also used to calculate ion composition and interpret the electron density variations under several special circumstances: severe storms associated with magnetic activity, solar eclipses, and F region sunrise transitions in the equatorial region. Observations of the electron density profile for extreme ionospheric storms are presented and discussed. It is demonstrated that an order of magnitude change in the F2 region loss coefficient, β, can account for the storm profile. Several mechanisms for increasing β are investigated. One of the most promising mechanisms involves vibrationally excited N_2 produced by electron collisions. The F2 electron concentration is calculated for two solar eclipses.

Comparison with observation gives the following production, q, and loss, β, rates at 300 km: $\beta \sim 1.4 \times 10^{-4} \text{sec}^{-1}$ and $q \sim 120 \text{ cm}^{-3}\text{sec}^{-1}$ for low solar activity, and $\beta \sim 7.6 \times 10^{-4} \text{sec}^{-1}$ and $q \sim 950 \text{ cm}^{-3}\text{sec}^{-1}$ at high activity. Finally, a simple explanation is presented for some unusual sunrise stratifications observed in the equatorial F region. Production and loss rates are derived which are reasonably consistent with the eclipse results.

This abstract is approved as to form and content. I recommend its publication.

Charles A Barth

Faculty member in charge of dissertation